IBM Corporation

Automated Tool Suite to Aid Interoperability of Manufacturing Execution Systems

In the mid-1990s, the U.S. electronics industry, which had an estimated compound annual growth rate of 10.5 percent, was one of the largest and fastest growing manufacturing industries in the nation. Its ability to respond quickly to market changes required a well-functioning manufacturing execution system (MES) that could provide up-to-the-minute information from the factory floor to front-office systems. These systems included customer-oriented manufacturing management (COMM) systems for accounting, planning, analysis, and decision-making. At the time, though, approximately 85 percent of the installed MES software was developed in-house, which made it difficult to upgrade or change.

In 1994, International Business Machines (IBM) Corporation received an award from the Advanced Technology Program's (ATP) focused program competition, "Computer-Integrated Manufacturing for Electronics" (renamed "Technologies for Integrated Manufacturing" the following year). IBM received funding for a two-year project to create an automated tool suite that would enable commercial software vendors to rapidly develop, maintain, and join families of interoperating products. To complete the project, IBM collaborated with the University of North Carolina in Charlotte, which conducted research and assisted with the development of the new technology.

In March 1995, a month after the ATP-funded project began, IBM changed the project focus from COMM planning and control systems to the more advanced enterprise resource planning (ERP) systems, which could integrate systems across an enterprise. By the end of the project in 1997, IBM had successfully developed an ERP/MES automated tool suite; however, the company chose not to commercialize products from the new technology. Instead, it commercialized services for linking applications of manufacturing software (enterprise application integration services), which are based on the technology developed during this project.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
*

Research and data for Status Report 94-03-0012 were collected during April 2003 – January 2004.

Forming "Families" of Applications Is Time Consuming and Costly

Manufacturing execution systems (MESs) are used by businesses to capture real-time data from factory floor information systems. These data include the availability of tools, labor, and materials; maintenance schedules; records of past process performance; and the status of work in progress. The data are then communicated either to front-office systems such as customer-oriented manufacturing management (COMM) systems, which are dedicated to accounting, forecasting, and other resource planning activities, or to the factory's design and engineering systems. In the early 1990s, many MES solutions were custom-developed by manufacturers for their own use. The systems were typically complex; they often comprised applications that were isolated from other factory processes or were linked by unique computer codes. Incompatibilities in the software and processes made it difficult for companies to upgrade or change applications.

To address these problems, many MES vendors started to form "families" of applications, such as MES/COMM

system applications, and to offer integrated software solutions to customers. However, the vendors were forming these families manually, determining the business rules and resolving business-rule differences between different systems, which was time consuming and costly. The cost of manually maintaining interoperability through frequent product upgrades was also high; product upgrades could take place as frequently as every six months.

Automation Tool Suite Could Reduce Cycle Time

International Business Machines (IBM) Corporation wanted to significantly reduce the cycle time (and, thus, the cost) to distribute, change, and integrate MES applications for the electronics manufacturing industry. Further, the company wanted to increase the use of MESs among electronics manufacturers. IBM planned to accomplish this by using a framework or structured approach to develop an automated set of tools for developing, maintaining, and joining families of interoperating products. The framework would include a reference model to guide vendors in the development of the interoperating products and to assist them in creating standardized products for specific processes or types of manufacturers. The framework would consist of three levels:

- *Top level:* the reference object model, which would include the definition of the interoperation boundary in a product family. This boundary is generally defined in terms of data objects, methods involving the data objects, and event triggers.
- *Second level:* vendor specifications.
- *Third level:* integration specifications between products within the same family.

The automated tools would include a workbench, or repository and software tools, which would be used to create and store the vendor specifications for each product, as well as an individual user's interoperation specifications. The tools would also include the business rules, such as activity management or accounting rules, for different MES/COMM products. Another automated tool would be a reengineering "assistant" to help a vendor update and link preexisting legacy software with newer software. The assistants would perform tasks such as the following:

- Recover business rules from program scripts
- Add event triggers to MES solutions, when necessary
- Use interoperation specifications to manage gaps that might occur when linking different products

IBM Anticipates Broad-Based Benefits

IBM believed that an automated tool suite, which would reduce much of the manual programming effort currently required, had the potential to significantly increase the speed with which MES vendors could develop, maintain, and join families of interoperating products. Electronics manufacturers would be able to obtain integrated products quickly and at a lower cost. This would lead to a significant increase in the use of MES solutions by electronics manufacturers throughout the United States, resulting in greater speed and efficiency within their manufacturing operations, as well as higher profits. IBM believed that eliminating incompatibilities in manufacturing and business software could trim production lead times by as much as 40 to 60 percent.

IBM wanted to significantly reduce the cycle time to distribute, change, and integrate MES applications.

Use of an automated tool suite would also lower a vendor's cost to develop family-based software. This would encourage more vendors to become involved in product family formation, which would increase competition and further lower the cost of the software.

IBM anticipated that after the first family of interoperating MES/COMM products was released, the company would realize revenue of several million dollars within 48 months from the sale of the products. The release of MES/COMM products could also potentially lead to an increase billions in revenue for the electronics manufacturing industry.

Development of Automation Tool Suite Poses High Risk

IBM understood that creating an automated tool suite was a high-risk endeavor. At the time, a significant

amount of manual programming was required to form product families. Many of the required activities, such as reengineering business rules and event triggers and maintaining the consistency of the legacy codes during product upgrades, would be performed differently with an automated system.

In particular, IBM anticipated difficulty in working with legacy software. It would be difficult to determine the existing data definitions, data manipulation rules, business rules, and application logic that trigger each legacy application's function. IBM would need to expose these features in order to manipulate elements in the system to resolve interoperation problems. Also, at the time, there was no industry-wide MES software interoperation standard, because of the diverse technological and business concerns of the different manufacturing enterprises. Without an MES industry standard, it would be difficult to quickly develop, change, and integrate MES software, even with an automated tool suite.

Because the project risks were more than IBM could assume at the time, the company sought financial support from ATP. They were awarded cost-shared funding in 1994 for a two-year project under ATP's focused program, "Computer-Integrated Manufacturing for Electronics" later subsumed into "Technologies for Integrated Manufacturing." This support would allow the company to develop an automated tool suite 18 months sooner than if IBM funded the project itself.

FAIME Technology Meets Project Goals

In March 1995, a month after the ATP-funded project began, IBM decided to expand its objectives and renamed the project, "Framework for Adaptive Interoperability of Manufacturing Enterprises (FAIME)." With FAIME, IBM planned to develop an object-oriented (OO) framework and to focus on interoperability between enterprise resource planning (ERP) and MESs. (An ERP system, which was capable of integrating systems across an enterprise, was a more advanced planning and control system than a COMM system.)

An OO framework would take all information related to a process and would create an object that could independently perform an operation within a system, as well as interact with other objects within the system. The automated tools developed with the OO framework would allow for "plug-and-play" interoperability between different applications. Therefore, ERP and MES applications could be interchanged without significantly disrupting the integration. The automated tools would provide the following benefits:

- Considerably reduce the time it took to perform software integration
- Facilitate the introduction of MESs into the customer's business processes
- Reduce the time it took to perform system maintenance and modification
- Improve the overall quality of integrated ERP/MES software performance

With the assistance of the University of North Carolina at Charlotte, IBM successfully developed a flexible, automated tool kit by the end of the ATP-funded project. The tool kit could be used to develop, maintain, and join families of ERP and MES applications, as well as other manufacturing interoperating applications. IBM demonstrated that it had successfully met its objectives by using the tool kit to integrate the following ERP and MES applications:

- JD Edwards' ERPX Version 6.2 (ERP application)
- SSA's BPCS Version 4.0 (ERP application)
- IBM's Factory Operation eXecutive Version 1.3 (MES application)
- SynQuest's EnSync Version 4.45 (MES application)

FAIME Technology Becomes Platform for Services and Other Software

By 1996, a year before the project ended, IBM had developed and had started to implement a strategy to promote and commercialize the FAIME technology. That year, it started to promote FAIME through presentations and demonstrations and by publishing several papers about the new technology. The company also started to make plans to commercialize the technology. For example, it planned to package and announce the new technology as an IBM service offering in June 1997, three months after the ATP-funded project ended.

By the end of the ATP-funded project, IBM had taken the following steps:

- Demonstrated the new technology to CMD Systems, a subsidiary of Deloitte and Touche
- Presented the new technology at the IBM ERP Symposium in April 1997
- Made potential plans to use the FAIME tool set to integrate JD Edwards' ERPX 7.1 into IBM's factory operations
- Met with SynQuest regarding the company's interest in marketing FAIME's integration capability
- Met with CMD Systems regarding a potential collaboration for using the FAIME tools
- Met with the IBM TelTech group regarding a potential customer for the FAIME tools

IBM anticipated that it would receive revenue from FAIME by 2000. However, after the ATP-funded project ended, the company decided not to use the new technology to manufacture products. Instead, it commercialized enterprise application integration (EAI) services based on the FAIME technology. IBM also used the FAIME technology as a platform for more advanced technology that it was developing in two other ATP-funded projects: CIIMPLEX (An Agent-Based Framework for Integrated Intelligent Planning - Execution) and EECOMS (Extended Enterprise Coalition for Integrated Collaborative Manufacturing Systems).

IBM used the FAIME technology as a platform for more advanced technology that it was developing.

The following paragraphs provide a brief description of IBM's EAI services and the two technologies, intelligent manufacturing planning and execution and intelligent supply chain logistics, that it developed in the ATP-funded CIIMPLEX and EECOMS projects.

EAI Services

After the FAIME ATP-funded project ended, IBM applied the technology it had developed to a service that linked manufacturing software applications. This service helps businesses automate the way in which different e-business applications and databases share and update data. The service creates an architecture that aligns disparate networks within the business and allows the networks to work together efficiently.

From 1997 to 2001, IBM earned revenues of $8.2 million from its EAI services. Its customer base also increased from 12 in 1999 to 25 in 2001; the largest customers were SynQuest and British Aerospace. In 2003, its EAI services included application connection services, message-oriented middleware services, business process services, object-oriented middleware services, and e-business security/directory services.

Intelligent Manufacturing Planning and Execution

Under the CIIMPLEX project, which began in March 1996, IBM took the concept of using a flexible framework to rapidly integrate manufacturing information and control systems, which was being developed in the FAIME project. The CIIMPLEX project included the linking of real-time manufacturing information with planning and execution systems through the use of basic algorithms (electronic step-by-step procedures). The new CIIMPLEX technology was to be a self-configuring plug-and-play MES framework, based on the use of intelligent software agents (automated processes that could perform a task ordinarily performed by humans). This framework could be used for integrated intelligent planning - execution applications.

In 2001, IBM began to sell MQServices Adaptor Offering (MQAO) and business-to-business (B2B) integrators, two software products that incorporated the CIIMPLEX technology. B2B was the software used to connect applications. MQAO was the tool set designed in the CIIMPLEX project used to develop the connectors between the applications and the B2B integrator. IBM earned revenues of $13 million in 2001 from sales of these two products.

Intelligent Supply Chain Logistics

In the EECOMS project, IBM took the concepts developed in FAIME and CIIMPLEX to design a new framework that allows people, applications, and intelligent software agents to collaborate on supply chain logistics in real time. (Supply chain logistics refers to the details of planning, scheduling, and controlling

the supply chain, which is a series of organizations and functions that produce or assemble materials and products from manufacturer to wholesaler to retailer to consumer.) The goal of the EECOMS project was to extend the capability of an MES by integrating supply-chain logistics across many organizations or enterprise boundaries.

The EECOMS solution would use intelligent, dynamic technologies for procurement and brokering, to which it would apply rules-based technology. The solution also offered information security (the protection of data against unauthorized access) and enabled users to construct virtual situation rooms, which are simulated rooms that could be used by groups to collaborate and manage supply chain problems from remote locations. As with the FAIME and CIIMPLEX technologies, EECOMS would involve a distributed computing environment that could readily accommodate the differences in the processes, practices, and software of supply-chain members.

After the FAIME ATP-funded project ended, IBM applied the technology it had developed to a service that linked manufacturing software applications.

Successful implementation of the EECOMS technology was expected to result in the more rapid delivery of products to customers, a reduction in costly inventories, and a further increase in the competitiveness of U.S. manufacturers in the global marketplace. The EECOMS project was completed in 2001. Since then, IBM has incorporated virtual situation rooms in several of its products, including its Lotus software.

Conclusion

With ATP's assistance, International Business Machines (IBM) successfully developed a new automated tool kit that could be used to develop, maintain, and join families of enterprise resource planning and manufacturing execution system applications, as well as other manufacturing interoperating applications. However, by the end of the ATP-funded project in March 1997, IBM decided not to commercialize this product. Instead, it commercialized enterprise application integration (EAI) services, which are based on the Framework for Adaptive Interoperability for Manufacturing Enterprise (FAIME) technology developed during this project. The company then focused on developing two more advanced technologies, business-to-business (B2B) integration and intelligent supply chain logistics. Both of these technologies used FAIME as the platform and were developed in two other ATP-funded projects: An Agent-Based Framework for Integrated Intelligent Planning - Execution (CIIMPLEX) and Extended Enterprise Coalition for Integrated Collaborative Manufacturing Systems (EECOMS).

As a result of the EECOMS project, IBM has developed and commercialized virtual situation rooms and has incorporated them into several of its products, including Lotus software.

From 1997 to 2001, IBM earned revenues of $8.2 million from its EAI services and, in 2001, $13 million from the sale of MQServices Adaptor Offering (MQAO) and business-to-business (B2B) integrators, two software products that incorporated the CIIMPLEX technology. Its EAI customer base also increased from 12 in 1999 to 25 in 2001; the largest customers were SynQuest and British Aerospace. In 2003, IBM's EAI services included application connection services, message-oriented middleware services, business process services, object-oriented middleware services, and e-business security/directory services.

PROJECT HIGHLIGHTS
IBM Corporation

Project Title: Automated Tool Suite to Aid Interoperability of Manufacturing Execution Systems (A Product-Family-Based Framework for Computer Integrated Manufacturing)

Project: To create an automation tool suite that would enable commercial software vendors to rapidly develop, maintain, and join families of interoperating products, which are sets of manufacturing and business applications that work together and can be updated in parallel.

Duration: 2/1/1995-3/31/1997
ATP Number: 94-03-0012

Funding (in thousands):**

ATP Final Cost	$1,864	59%
Participant Final Cost	1,296	41%
Total	$3,160	

Accomplishments: ATP funding enabled International Business Machines (IBM) to develop an automated tool kit that could be used by vendors to develop, maintain, and join interoperating families of enterprise resource planning (ERP) and manufacturing execution system (MES) applications.

Commercialization Status: IBM did not commercialize its new automated tool kit. Instead, it commercialized a service based on its new Framework for Adaptive Interoperability of Manufacturing Enterprises (FAIME) technology, enterprise application integration (EAI) services. The company also focused on the more advanced business-to-business (B2B) integration technology that it was developing in another ATP-funded project, An Agent-Based Framework for Integrated Intelligent Planning - Execution (CIIMPLEX) and the intelligent supply chain logistics technology that it later developed in the ATP-funded project, Extended Enterprise Coalition for Integrated Collaborative Manufacturing Systems (EECOMS).

By 2001, IBM had earned revenues of $8.2 million from its EAI services. The company had also earned revenues of $13 million from sales of MQServices Adaptor Offering (MQAO) and B2B integrators, two software products developed during the CIIMPLEX project. In 2003, IBM continued to offer EAI services and has incorporated virtual situation rooms, which were developed in the EECOMS project, into several company products, including Lotus software.

Outlook: The market for EAI services continues to grow for IBM, as well as for other firms. In 2003, EAI services that are in demand include application connection services, message-oriented middleware services, and business process services. IBM also continues to sell its B2B integrators and products that include virtual situation rooms. The company has no plans to commercialize its automated tool kit for developing, maintaining, and joining interoperating families of ERP and MES applications, which was the original target product of this project.

Composite Performance Score: *

Focused Program: Computer-Integrated Manufacturing for Electronics (renamed Technologies for Integrated Manufacturing the following year), 1994

Company:
IBM Corporation
11501 Burnet Road
Austin, TX 78758-3407

Contact: Vincent Meriwether
Phone: (512) 838-4711

Subcontractor:
University of North Carolina at Charlotte
Charlotte, NC

Publications:
The group also shared its project research in the following publications:

- Chu, B., J.S. Long, M. Matthews, J.G. Barnes, J. Sims, M. Hamilton, R. Lambert. “FAIME: An Object-Oriented Methodology for Application Plug-and-Play,” *Journal of Object-Oriented Programming*, 11(5):20, September 1998.

- Sims, J.E., B.B. Chu, J. Long, M. Matthews, J.G. Barnes, C.H. Jones, R.A. Anderson, R. Lambert, D.C. Drake, M.A. Hamilton, M. Connard. “Framework Adaptive Interoperability of Manufacturing Enterprises (FAIME)-A Case Study; Plug and Play Software for Agile Manufacturing Track,” *Proc. of the International Society for Optical Engineering*, vol. 2913: 289-303, 1997.

** As of December 9, 1997, large single applicant firms are required to pay 60% of all ATP project costs. Prior to this date, single applicant firms, regardless of size, were required to pay indirect costs.

- Drake, D., B. Chu, J. Sims, R. Anderson, M. Hamilton, R. Lambert, M. Connard, J. Long, A. Sartin, E. Wayne, J. Chen. “Framework for Application,” *Proc. of the International Society for Optical Engineering*, vol. 2913: 267-88, 1997.

Presentations:

IBM disseminated knowledge gained during this project through the following presentations:

- IBM ERP Symposium, 1997.
- Chang, Robert. Enterprise Resource Planning Symposium, 1996.
- Long, Junsheng. Continuous Acquisition and Life-Cycle Support/Concurrent Engineering Conference, 1996.
- Sims, John. National Center for Manufacturing Sciences Conference, 1996.